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Interdisciplinary Construction of a Socio-ecological Vulnerability Trajectory Based on the Quatre Montagnes (Isère, France) Area from 1950 to 2016

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AUTHOR'S NOTE

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Introduction

1 The study of the vulnerability of a landscape requires intersecting ecological processes with political and socioeconomic dynamics of different types and at different spatio-temporal scales. This involves an interdisciplinary dialogue between the human and social sciences drawing on new paradigms that take the environment into account (Beck *et al.*, 2006; McNeill, 2010; Hamman, 2017) and between these two branches of science and the natural sciences (MAE, 2005; Diaz *et al.* 2015). This notably involves the improvement of adaptive governance, which must meet the challenge of global change (Colloff *et al.* 2017). Achieving such an objective requires that interdisciplinary actions facilitate the

construction of knowledge on nature–society interactions by formulating or creating compatibilities between diverse concepts, sources, and methods.

2 This article reports an experience of interdisciplinary exchanges between researchers in ecology, geography, and sociology –the exploratory project "CHRONO-SE"– conceived in a context of research on mountain landscapes based on scientific partnerships (LabEx ITEM [1], GICC ADAMONT[2]). This involved experimenting on a particular landscape –Quatre Montagnes, corresponding to the current Vercors Mountains association of municipalities– the co-construction of a vulnerability trajectory on a single timeline, notably based on articulating concepts of resources used by human and social sciences, and bundles of ecosystem services developed by ecology.

3 This article compiles the lessons learned from the usage protocol of the chronosystemic timeline used as an interdisciplinary tool (Bergeret *et al.* 2015) and reports the numerous problems and critical issues that this short project raised. The first part describes the conceptual and methodological framework and the second part the results in terms of both knowledge and method.

Conceptual and methodological framework

Connections between disciplinary concepts

4 From a theoretical perspective, the working group suggested linking different sociological and ecological concepts: landscape and socio-ecosystem, resource and ecosystem service, and finally vulnerability.

5 The notion of landscape, as it is used in economics, geography, and sociology, stresses the appropriation and social construction of a space (Gumuchian and Pecqueur 2007) by studying the structures, social actors, interactions, and balance of power in the construction of practices, institutions, and policy-making processes. The notion of the socioecological system accentuates the functional relationships of interdependence, and the flow between ecosystems and human activities (Liu *et al.*, 2007; Díaz *et al.*, 2015), and is applied to drawing up the operational frameworks for policy-making processes (Barreteau et al., 2016).

6 The same complementarities should be underscored between ecosystem services and resources. Ecosystem services relate socioeconomic demands and the capacity of the ecosystem to provide the services needed and to ensure its supporting and regulation functions (MAE, 2005). The potential of this concept as a transdisciplinary boundary object is perceived (Steger *et al.*, 2018), although all precaution may applied to its use (Kull et al., 2015). Recent readjustments (Diaz *et al.*, 2018) have in fact recognized the sociocultural dimension present transversally in the different services. It therefore seems advantageous to bridge the gap using the resource approach in the social sciences, designating the social process of wealth generation: each of the approaches provides a better understanding of one of the two poles of the interaction between the capacity of the ecosystem and human activity. In addition, the notion of a landscape resource adds an essential dimension to the study of vulnerability trajectories: by coordinating the actors of a given landscape, the process of specification and grounding the resource in its landscape could supply its identity (Gumuchian and Pecqueur, 2007; Janin et al. 2016). Finally, trade-offs, assessed in bundles of services, would allow considering the ecological

stakes of an action in a unified fashion, with the possibility that contradictions between them exist (Raudsepp-Hearne *et al.*, 2009), with certain human activities, for example, inducing supply services that would create tension for the support and regulation services.

7 Finally, we include this vulnerability trajectories approach within the sociological, economic, and historical studies that have a common goal of considering landscape dynamics as complex, irreversible processes that mobilize different types of scales, mixing relations of causality and dependence with the pathway, i.e., all phenomena of emergence, transition, and rupture (Mendez, 2010; Fischer-Kowalski and Haberl, 2007; Geels and Schot 2007; McNeill, 2010). The "metabolic" visions combining systems of all types of actors and flow (Fischer-Kowalski and Haberl, 2007; Buclet, 2015) construct an even narrower bridge with ecologists.

8 According to ecologists, the relevance of the study of vulnerability is no longer limited to the risks to or the vagaries of the environment (IPCC, 2001), to the individual capacity to meet the challenge of a stress or a change (Allen, 2003), or to the elaboration of aggregated indices based on a multiplicity of generic indicators (Adger, 2004): ecologists propose a dynamic and multidimensional vision of resilient and adaptive cycles combining capacities of resistance, learning, and transformation (Walker et al. 2004). We conclude from this that the comprehension of vulnerability stems from interrelations between exposure to environmental vagaries and the sensitivity of ecosystems to these ups and downs, and the specificities of local socioeconomic configurations and dynamics in their ability to adapt. We will break down this second aspect (starting from the above-mentioned details as well as Magnan, 2012; Berrouet, 2018) through: a) the sensitivity of the social system encountering modifications in ecosystem services, the degree of insecurity and solidarity within the local population; b) the capacity to adapt and transform activities, determined based on the degree of independence compared to the local resources, as well as the capacity to anticipate, coordinate actors, and construct territorial resources; and c) the degree of interdependence, marginality, and solidarity with the surrounding areas at the local and national levels.

Methodological objective and protocol

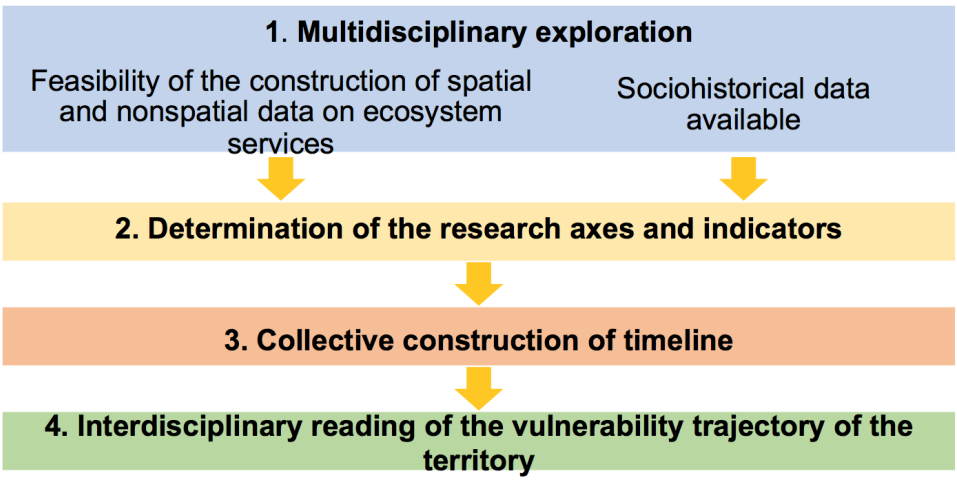
9 Within the methodological perspective, the above-mentioned theoretical proposals require trajectory representation tools that can simultaneously consider the socioeconomic and ecological dynamics of a landscape or socio-ecosystem, put in perspective their synchronies and asynchronies, and assess the force of the impacts of one level on another, whether they be multiplier, dampening, compensation, or threshold effects. The working group chose to use the principles of the chronosystemic timeline (Elissalde, 2000), assisting an interdisciplinary construction tool of the complex processes at work in the landscape (Bergeret *et al.*, 2015). This presents the different dimensions (e.g., economic, ecological, political) of a landscape trajectory on different research axes and embodies the relations between landmarks, making it possible to understand procedural dynamics. This organization along various research axes can bring out divergences, alignments, and crossroads between the perimeters of different dimensions of change in the landscape as they are studied over time.

10 The objective of the exercise was therefore to create an aid to collectively identify the vulnerability trajectories on a particular landscape and to test whether the

chronosystemic timeline was a sufficiently robust boundary object to advance knowledge that was also sufficiently flexible to be appropriated, to adapt to the specific constraints of each landscape, and to express diverging interests. We describe herein this tool's quality as an "intermediary" of knowledge, i.e., its capacity to assist the cognitive actions of the scientific community (Vinck, 2009).

11 Given the short duration of the project – programed for five meetings – the choice of a research terrain was restricted by the availability of data: the Quatre Montagnes area was being studied within the GICC ADAMONT project. The time step studied was reduced to the data available for the second half of the twentieth century. The strategy adopted was "to learn by doing," while noting the methodological problems stemming from the protocol proposed (Figure 1), which will be detailed in the following part. The last session was used to validate the elements of the timeline with a specialist on the area and to critically assess the method.

Figure 1 : Protocol proposed for the interdisciplinary lecture of a landscape's vulnerability trajectory



Authors, 2018.

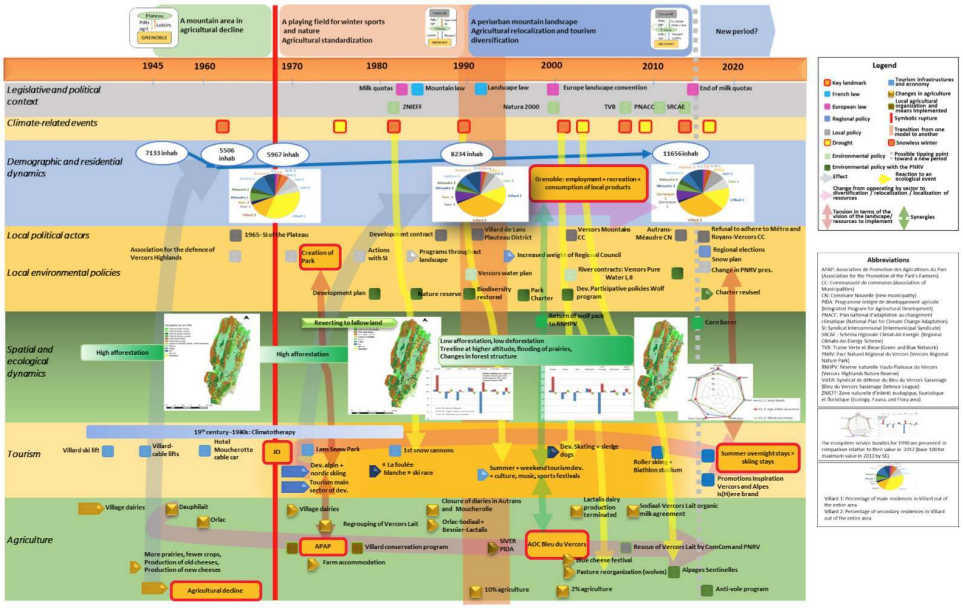
Results and discussion

12 In this second part, we present the results in terms of knowledge and critically evaluate methodological issues raised during the experiment.

Timeline and landscape trajectory

13 The resulting timeline, presented in Figure 2, remains a working document used for the methodological questions raised. It therefore does not claim to present a definitive analysis and indeed suggests hypotheses to verify, to triangulate with specialists of the Vercors landscape, which the participants in this experiment were not.

Figure 2. The Quatre Montagnes (Vercors, France) socio-ecological trajectory from 1945 to 2016



Les paramètres nécessaires sont manquants ou erronés.

Authors, 2018.

14 This timeline proposes the selection of landmarks, interactions, and periods put together by the working group, structured along different research axes:

- The legislative and political context at the French and European levels and the climate-related events;
- The demographic and residential dynamics;
- The local political dynamics, focusing on the actions of the Vercors Regional Nature Park (Parc naturel régional du Vercors, PNRV);
- The spatial and ecological dynamics of the water, forest, and environmental resources and the bundles of ecosystem services provided;
- The transformations of resources implemented in tourist and agricultural activities (focusing on the dairy sector).

15 At the end of this experiment, the working group discussed the hypothesis of a landscape trajectory divided into four periods (summarized in the top line), which will be detailed in section 2.3, successively organized as follows: 1) a connected rural area, 2) a mountainous area in agricultural decline, 3) a winter sports area, with preservation and nature as key goals, and 4) a periurban area seeking relocation and diversification.

The timeline construction stages

Multidisciplinary exploration

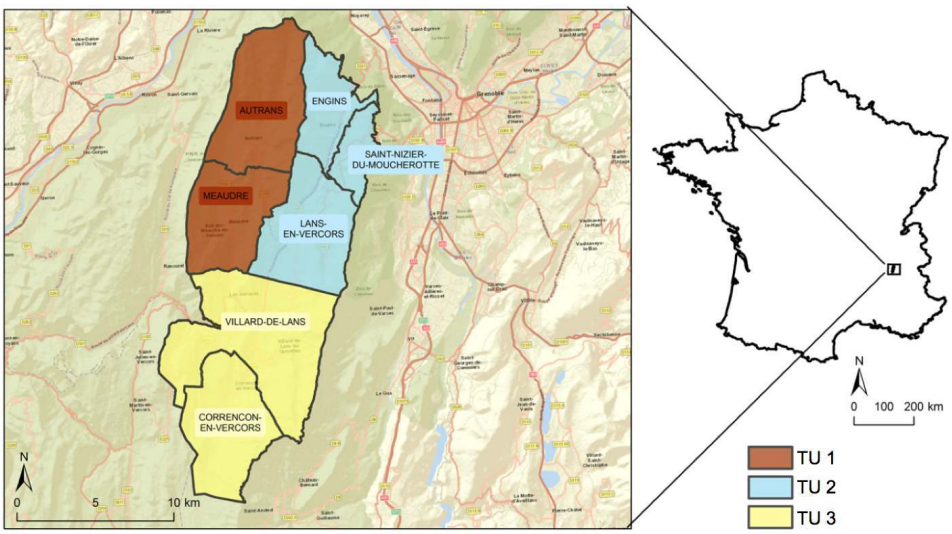
16 The preliminary stage consists in identifying the different perimeters of the area, both the ecological functional units and the living areas (relations between the Vercors Plateau area and the neighboring towns) and the political-administrative entities (construction of intermunicipality relations and the regional nature park). At the same time, a selective review of the literature in history, sociology, and economics available on this area (see list

in the appendix) gives a first approach to the socioeconomic transformations, institutional construction, striking events, and resources implemented. A more exhaustive exploration could have improved the detail of the analysis of the historic process.

17 From the ecologists' perspective, we attempted to establish socio-ecosystemic units combining data on land use, wetlands, the cadastral maps for agricultural land, and the extent of forest areas, but this was not possible in the time allotted to the study. Cadastral maps for 1956, 1981, and 2009 (from the FORGECO[3] project) and 2012 (ADAMONT) were used to visualize the evolution and distribution of habitat types, mainly forests and urban areas.

18 This first step concluded in a discussion on whether or not spatial subsets existed that had undergone contrasting changes, from both sociological and ecological points of view. The discussion ended in a proposal to test how three township units contrast in terms of their development (TU; Fig. 3). These three subsets also correspond to subsets identified in the documents of the Vercors Mountains association of municipalities (CCMV, 2015).

Figure 3. Map showing the area covered by the Vercors Mountains association of municipalities and its township units (TU1 to TU3)



Authors, 2018.

Determination of the research axes and indicators

19 This stage, based on exploratory data, consisted in collectively determining the components of landscape change to observe in each research axis, as presented above.

20 The next step was to choose the indicators to assess the socioeconomic activities and the bundles of ecosystem services. This was a crucial explicative and translational step between ecology and the social and human sciences, which should make it possible to select all the quantitative, qualitative, and spatial variables useful to understanding the content of the resource, and to follow the state of society and the ecosystem over time.

21 For the socioeconomic data, it was suggested to observe the demographic and residential INSEE data. Other indicators such as employment, transportation, commuting and seasonal migrations could not be systematically explored.

22 The ecological indicators were selected from the ESNET project[4] (Table 1) around the changes in forage activity, the extent of the forest, the state of the soils, and biodiversity. Here again, this choice was made within constraints: the problems raised by this choice uncovered three types of pitfalls to avoid.

23 The first stems from the choice of services selected to constitute a coherent bundle regarding the resources studied: this choice let aside indicators e.g., of other agricultural services that could not be implemented. More detailed indicators of soil management would have been useful, e.g., the passage from conventional to organic management of an agricultural parcel modifies the ecosystem services provided in terms of productivity, soil fertility, and water quality. Similarly, the integration of services such as the tourist attractiveness of a landscape could have been integrated.

24 The second limitation is related to the importance of adapting the description of the services to the scale of the area selected. In the present case, services were quantified by extracting the results of a project that had targeted a broader geographic territory.

25 The third limitation stems from the parameterization of the indicators. The method used to reconstruct how ecosystem services had evolved was based on the calculation of the mean value per service in 2012 and per township unit on each of the categories of the Corine Landcover, to then be applied to the bundles of ecosystems services associated with each township unit in 2000 and 1990. This method of projecting into the past based on the 2012 values carries a risk of errors and of being archaic because the values of the services may have evolved over time. Recourse to a historian's work is therefore indispensable to refine the coefficients applied to production services, inputs, and the externalities of the different past economic activities.

Table 1. Ecosystem services and indicators of biodiversity considered to draw up the bundles of ecosystem services by township unit

Category	Variable	Description	Justification for the landscape
Supply service	**Animal feed production**	Forage yield standardized as energy yield (Giga Joules/ha)	Large livestock breeding activity
	Wood stock	Volume of standing timber (m^3/ha)	Large forest area
Regulation service	**Water infiltration capacity**	Relative index of water volume infiltrated in soil	Management of water resources on karstic mountain area
	Erosion control	Relative contribution of ecosystem to limitation of erosion risk (classes)	High risk in mountain area
	Carbon stock	Quantity of organic carbon stored in above-ground , underground, and soil biomass (tC/ha)	Contribution to global issues
Biodiversity	**Habitats for fauna**	Number of vertebrate species for which habitat is favorable	Source area/sensitive refuge for biodiversity in periphery of metropolitan area
	Habitats for flora	Number of plant speices for which habitat is favorable	Source area/sensitive refuge for biodiversity in periphery of metropolitan area

Authors, 2018.

26 The results of this work led to the following observation: TU1 maximized forage productivity values, notably compared to TU3, whereas the stock of standing timber appears more consequential on TU1 and TU3. The capacity for limiting soil erosion is lower on TU3, possibly related to its contrasted topography.

27 Temporal variations between the 3 years studied, in terms of bundles of services, are small and are interpreted as low impacts of socioeconomic changes on ecosystem services. However, it is probable that focusing on administrative units rather than functional units, as well as the use of data gathered for a larger geographic area, explain this lack of variability.

Group production of the timeline

28 This stage consists in selecting the striking events, trends, and configurations identified during the first two stages, indispensable to understanding the trajectory of the landscape resource and vulnerability trajectories, and to place them in the timeline as well-ordered landmarks on each axis. This work was conducted in workshops around a large timeline so that all knowledge could be shared.

29 During these exchanges, the timeline became the medium receiving hybrid knowledge, a heterogeneous assemblage of information with different formats (INSEE curves and diagrams, photographs of landscapes, historical, geographic, and agronomic work, radar charts of bundles of ecosystem services, and land use maps; Figure 3). Transferring these data to a visual timeline allowed the group to refine the process and the finished product.

Interdisciplinary reading of the vulnerability trajectory for the Vercors landscape

30 Once the landmarks had been identified, the vulnerability trajectory was deliberated and drafted. The working group decided on a) the key landmarks (events indicating a rupture or a junction; significant trends that resulted in a change throughout the area) and b) the time periods, their time markers (and how to describe them: ruptures, junctions, transitions, adaptations), and the interactions that should be evidenced to understand the dynamics inherent to each phase as well as the passage from one time period to another. Most particularly, here these transitions concerned the assessment of the interactions between policies, socioeconomic changes, and the environment (relationships of cause and effect, succession, resistance, or contradictions), to appreciate the coherence of the resources put into effect, the forms of vulnerability as they had been defined.

Key landmarks

31 Seven key landmarks were noted collectively, turning points that facilitate a preliminary general evaluation of the (de)synchronizations, overlaps, and relations of cause and effect between different dynamics:

- Tourism: the 1968 Olympic Games, the initial point of the development of winter tourism in the Vercors Mountains, and 2015, when summer activities brought in more in terms of overnight stays than skiing activities (INSEE, 2016);

- Socioeconomics: the trend toward a loss of agricultural assets and toward periurbanization around the Grenoble metropolitan area;
- Relation to the environment: the impulse given to taking into account ecological considerations beginning with the creation of the Vercors Regional Nature Park in 1970;
- Agriculture: relocation of agricultural resources launched in the 1970s, which symbolically resulted in the creation of the Vercors-Sassenage blue cheese AOC in 1998.

Periodization and vulnerability trajectories

32 The interdisciplinary reading stage around certain periods allows an exchange of arguments around salient interactions and the resulting forms of resource development and different vulnerabilities, for each one of the phases.

33 In Period 1, between the middle of the nineteenth century and 1945, the Quatre Montagnes was a "connected rural" area. Agriculture, the dominant activity (livestock breeding and forage crops), allowed a certain self-subsistence and exchanges with the neighboring areas. Tourism developed with climatotherapy and the first skiing infrastructures. These elements favored the development of roadways and an electric tramway between Villard-de-Lans and Grenoble between 1920 and 1951. The population was on the rise in 1930. The landscape closed because of low deforestation and high afforestation. Social relations were marked by proximity, as were nature–society relations: the working group hypothesized low vulnerability because of the independence of the local resources, local solidarity, and positive exchanges with the surrounding area.

34 Period 2, between 1945 and 1968, can be defined as a period of declining agriculture, marked by afforestation, the rural exodus, and threatened by disconnection: the number of inhabitants dropped from 7133 to 5506 between 1946 and 1962, before starting to rise again, which was reinforced in the following period. The dependence on the Grenoble employment area increased, whereas the tramway was dismantled. The forms of vulnerability therefore evolved: on the one hand the reconstruction needs and the trauma brought on by the Second World War, and on the other hand the national aid contributed by Reconstruction and Agricultural Reconstitution (Brunier, 2013). Agriculture was also deeply restructured because of the incitement to modernization and high productivity. The regional milk collection and transformation were beginning to get organized. The area continued to be marked by health tourism (climatotherapy). All these movements, added to afforestation, announced a "re-wilding" trajectory, a "natural reserve" landscape (Perret, 2003). This is the framework in which emerged the wilderness protection groups: the Association of the Vercors Highlands (1965) and the status of the area's park as a regional nature park (1967), although the force that the emerging dynamics of winter sports was going to take was not fully understood.

35 Period 3 (1968 to the 1990s) was symbolically inaugurated by the tipping point of the Olympic Games both in the memories of the actors and in the mode of land use development: since then the Vercors Mountains became a spearhead of the medium-altitude winter resorts. The impulse given to sports facilities and winter activities curbed or even inversed the earlier dynamics (slowing down afforestation, increased population growth, and urbanization), radically transforming the resources put to work in the area and its forms of vulnerability. However, this new activity was not reflected by radically visible impacts on landscape and ecosystems.

36 Since skiing had become the pillar of the area's development, climatic uncertainties gave rise to incremental adaptations: after a snowless winter in 1981, Villard-de-Lans innovated by installing the first snow cannons in the Alps.

37 In agriculture, the period was one of enlargement and intensification, with the final products now standardized. The arrival of large producers finished sweeping out the small local factories transforming within the area agricultural products.

38 Vulnerability can here be assessed through the genericity of the resources generated, in both tourism and agriculture: they pulled the area into an extended competition, a sensitivity to the fits and starts of the national economy, and a dependence on the cold weather and snow conditions. However, this tidal wave should not overshadow the seeds of resistance on the part of local actors to maintain an identity of local production, which would bear fruit during the following period.

39 In addition, the simultaneous occurrence of the skiing activity, the creation of the Vercors Regional Nature Park in 1970, followed by the national legislation in favor of the environment, as well as the actions undertaken by the Association for the Promotion of the Park's Farmers (Association pour la Promotion des Agriculteurs du Parc; APAP), demonstrated the contradictions between the different visions for the area, between landscapes modeled by winter recreational activities, safeguarding agricultural activities, and the protection of wilderness areas (Perret, 2003). These instances provided room for discussion, compromises, and adapted governance around these issues, which reduced the area's vulnerability.

40 The passage from Period 3 to 4 cannot be identified by a particular event: it stems from a progressive transition, with diverse impulses in different agriculture and tourism dynamics that began in the 1970s and 1980s.

41 In Period 4 (1990–2016), urban growth stemming from tourism slowed down (in light of the progression in the number of second homes), in favor of periurbanization, which widened the gap between the township units of the area.

42 An ecosystemic vision of the landscape was structured, taking into account environmental issues: biodiversity, water, and the place of the wolf (Mounet, 2006): all engendered specific policies, negotiated between the local actors.

43 The problems that the genericity of the resources implemented could raise, sooner or later, were anticipated: dynamics attempted to relocate activities and to foster the identity of the area by coordinating farmers, the Park, and local authorities, which allowed setting up the Bleu de Vercors-Sassenage AOC (Madelrieux *et al.*, 2015; Janin, 2016). Recurrence of drought years resulted in pilot strategies around the "Sentinel Mountain Pasturing" program, contributing to the adaptability of the pasturing activity.

44 Similarly, the area anticipated the impacts of climate change for the skiing activity: the reaction to the snowless winters differed from the reaction in the 1980s, stemming from a transformative adaptation: beginning in the early 1990s, the trend was diversification of the supply of summer and weekend cultural and recreational activities.

45 However, despite the process of local identification of these different resources, they remained a contrasting association and the coordination of public and private actors remained relative (Hirczak *et al.*, 2008; Janin *et al.*, 2016). After having served the different micro-regions formed by the intermunicipal relations, the Regional Nature Park seeked to become an actor integrating the area's overall ecological issues. It sought to forge its

place between the intermunicipal, departmental, and regional authorities (Gerbaux and Paillet, 2000), attempting to anchor social innovation strategies over the long term through appropriation by local actors, but it was out of sync with the timeline of the political mandates (Cosson and Delorme, 2015).

46 Decrypting periodization ended in a debate around 2016: would this periodization be a turning point for the area given the reversals in regional policy, changes in governance of the Regional Nature Park, and the revision of the Charter?

Conclusion

47 Assessment of vulnerability, as defined herein, makes co-construction of knowledge by the human and social sciences and natural sciences necessary. The test comprising a historical reconstitution of the socio-ecological dynamics of a defined area, using both the finesse of the data and the cartography they require, as well as challenging the variables adopted to measure ecosystem services, has shown the methodological problems that must be overcome. At the same time, these critical issues have allowed us to draw up a reproducible methodology and to show how rich the approach can be in terms of mutual contributions that serve to refine the qualitative, quantitative, and spatialized knowledge on nature–society interactions. The project succeeded in initiating the shared idea that the chronosystemic timeline could function as a boundary object, providing its "persuasive proofs during which reasoning becomes the subject of intersecting assessments" (Chateauraynaud, 2011), thus opening possibilities for interdisciplinary studies.

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APPENDIXES

Appendix 1. Sources used in collecting data in the human and social sciences

Demographic and residential dynamics axis

- Données INSEE : démographies, densité, résidences principales, secondaires par chaque commune de la CCMV pour les années 1946, 1954, 1965, 1968, 1975, 1982, 1990, 1999, 2008, 2013.
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Local policy and PNRV axis

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NOTES

1. LabEx ITEM - Innovation et Territoires de Montagnes. Funded by the "Investissements d'Avenir" program administered by the Agence Nationale de la Recherche (ANR-10-LABX-50-01).

2. ADAMONT project (2015–2017). Impacts of climate change and Adaptation in mountain areas. Funded by the Programme Gestion et impacts du changement climatique (GICC) and the Observatoire national sur les effets du réchauffement climatique (ONERC).

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ABSTRACTS

The study of socio-ecosystems, their vulnerability, resilience and trajectories often requires collaboration between the human and social sciences, and the natural sciences. This article proposes to test this notion of socio-ecosystem and a methodology around the chronosystemic timeline as intermediate tools of interdisciplinary knowledge. It reports on an interdisciplinary experience, its research context, as well as its conceptual and methodological framework, illustrated with the example of the Quatre Montagnes in the Vercors Mountains (French Alps). It proposes a protocol that can be applied to monitoring the vulnerability trajectories of an association of municipalities and its environmental resources in an interdisciplinary perspective. The process consists of four stages: i) a sociohistorical and ecological exploratory step, ii) the determination of the dimensions to be observed and their indicators, iii) the construction of the

timeline, and iv) the analysis of the vulnerability trajectory of a landscape including its actors. This article presents the potential, the methodological difficulties, and the critical issues of this interdisciplinary analysis.

INDEX

Keywords: chronosystemic timeline, vulnerability, boundary object, interdisciplinarity, Vercors, resources

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